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Impact of Cricket and Caterpillar Meal Supplementation on the Nutritional Profile and Consumer Acceptability of Cookies

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The quality of cookies produced from wheat flour, cricket, and caterpillar meal blends was evaluated. This was done to examine the effect of adding edible cricket and caterpillar meals on the nutritional and sensory quality of wheat-based cookies. Edible crickets and caterpillars were purchased from local farmers in Benue state, de-gutted, washed, oven-dried, sorted, milled, and sieved to produce their respective meals. The meals were mixed in wheat flour: edible insects ratios of 95:5, 90:10, 85:15 and 80:20 for Cricket and Caterpillar meal blends, respectively. However, samples 100:0 were not mixed and contained 100% wheat flour. The samples were subjected to functional analysis of proximate composition, mineral, vitamin, amino acid profile, physical properties analysis, and sensory attributes evaluation. The result generated from the study was

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subjected to analysis of variance (ANOVA) and the Duncan multiple range test (DMRT) was used for mean separation at the probability level of significance of 5%. While the protein, fat, ash, crude fibre, and moisture content of the cookies increased with increasing amount of edible insect meal incorporated into the formulation, the carbohydrate content of the cookies decreased significantly ($p<0.05$). All minerals evaluated in the study (Ca, Zn, K, P, Na, Mg, and Fe) increased with the increase in the amount of edible insect meals in the formulations. An increase in vitamin content was also observed in the cookies, but this increase was insignificant ($p>0.05$). There was a significant increase in all essential and non-essential amino acid content of the cookies as the level of cricket/caterpillar meal in the formulation increased. The addition of up to 20% of edible cricket/caterpillar meals to wheat flour increased all sensory attributes of the cookies. Cookies fortified with caterpillar meal were found to be more nutritious than those fortified with cricket meal. In general, samples 85:15(85% wheat flour + 15% cricket meal) and 85:15(85% wheat flour + 15% caterpillar meal) contained high nutritional content and recorded the best sensory attributes and therefore were selected as the best blends for a wheat flour+cricket meal and wheat flour+caterpillar meal blends for cookies production.

Keywords: Nutritional profile; cookies; consumer acceptability; physicochemical and antioxidant properties; biscuits.

1. INTRODUCTION

Crickets are increasingly recognized as a sustainable and nutritious food source, rich in proteins, fats, vitamins, and minerals. They offer high protein content (42%-73% of dry matter) [1] and varying fat content (4.3%-33.44%), with a high proportion of unsaturated fatty acids [2]. Crickets are known to contain abundant essential minerals such as calcium, magnesium, iron, zinc, copper, and manganese, often exceeding those in conventional sources (Magara et al., 2021). They also provide a variety of vitamins, including B group vitamins and vitamins A, C, D, E, and K, contributing significantly to daily nutritional requirements. With a well-balanced amino acid profile, though slightly deficient in histidine and cysteine [3], and chitin beneficial for gut health, crickets exhibit significant antioxidant properties [4]. Overall, crickets are a promising alternative to traditional proteins, and integrating cricket powder into food products can address nutritional deficiencies and enhance food security.

Caterpillars, such as *Cirina butyrospermi, Imbrasia oyemensis, Hemijana variegata, Gonimbrasia cocaulti,* and *Imbrasia epimethea*, exhibit a rich nutritional composition suitable for human and animal consumption. These caterpillars are high in protein, ranging from 44.5% to 62.74%, with essential amino acids constituting a significant portion of the protein content. They also contain moderate to high levels of fat, essential minerals like potassium, iron, phosphorus, magnesium, calcium, and trace elements. The fatty acid profiles of these caterpillars show variations, with notable levels of linolenic acid and stearic acid. Additionally, the caterpillars provide vitamins such as B6, B9, B12, and α-tocopherol, contributing to their nutritional value and potential as alternative sources of protein, fat, minerals, and vitamins for human and animal diets [5-7].

Cookies are chemically leavened products, also known as 'biscuit' (Farheena et al*.,* 2015). They are ideal for nutrients availability, palatability, compactness, and convenience. They differ from other baked products such as bread and cakes because they have a low moisture content, comparatively free from microbial spoilage, and long shelf life of the product (Farheena et al., 2015)**.** Cookies hold an important position in snack food due to variety in tastes, crispiness, and digestibility. They are ready to eat, convenient and inexpensive food products, containing vital digestive and dietary principles. Apart from their rich nutrition, they are an excellent vehicle for introducing necessary ingredients needed by the body, hence making it a useful tool to meet the nutritional requirements of the increasing population.

This study therefore sought an alternative protein source by incorporating cricket and caterpillar meals into wheat flour used for the production of cookies to eliminate the over-reliance on conventional animal proteins.

2. MATERIALS AND METHODS

2.1 Sample Collection and Processing

Crickets and Caterpillars were both obtained from Tyo-Mu village and Gboko market-Katsina

Ala local government respectively, all in Benue State. The insect meals were prepared as outlined in Fig. 1.

2.1.1 Production of cookies

Five samples of cookies were formulated and produced with slight modifications from the methods of Oluwamukomi et al. (2011). The dough was made from a mixture of 100 g of wheat, 15 g of white sugar, 0.5 g of baking powder, 1 g of flavor, 30 g of egg, and 25 g of fat. The prepared dough was continuously mixed until a smooth consistency is obtained. The dough was kneaded and rolled thinly on the cutting board where it was cut into uniform shapes and sizes using a cutter. The cut dough was placed on a greased baking tray and transferred to the oven. Cookies were baked at 180 ° C for 20 min, cooled and packaged.

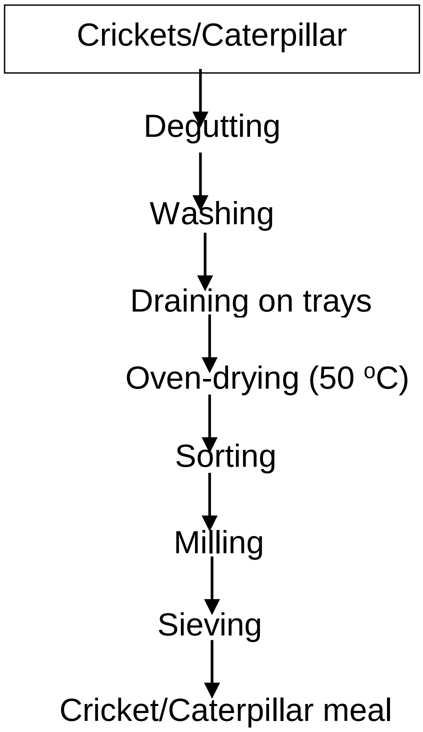

Fig. 1. Flow chart for production of cricket/caterpillar meals

Table 1. Recipe for the production of cookies

Ingredients	Quantity (g)
Flour	100
White sugar	15
Baking powder	0.5
Flavour	1
Fat	25
Egg	30

Source: Adapted from Oluwamukomi et al. (2011)

Table 2. Blend formulation (%) for the production of wheat / cream cookie cookies

Sample	Wheat Flour (%)	Insect meal (Cricket or Caterpillar)
A	100	0
B	95	5
C	90	10
D	85	15
E	80	20

2.2 Analytical Methods

2.2.1 Determination of the proximate composition of insect meal-supplemented cookies

The proximate parameters were determined according to the official methods of AOAC [8] Moisture content was determined using the air oven dry method. A clean dish with a lid was dried in an oven at 100ºC for 30 min, then cooled in desiccators and weighed. Two (2) grams of sample were weighed into the dish. The dish with its content was then put in the oven at 105ºC and dried to a fairly constant weight. The loss in weight from the original sample (before heating) was reported as percentage moisture.

$$\%\,Moisture = \frac{Weight\ loss\ of\ sample}{Weight\ of\ original\ sample} \times 100 \quad (1)$$

For the ash content, 2 g of the sample were weighed into an ashing dish which before use was pre-heated, cooled in a desiccator, and weighed soon after reaching room temperature. The crucible and content were heated in a muffle furnace at 55ºC for 6-7 h. The dish was cooled in a desiccator and weighed soon after reaching room temperature. The total ash was calculated as the percentage of the original sample weight. The ash content was calculated as

$$\%\,Ash = \frac{Weight\ of\ ash\ after\ ignition}{Weight\ of\ sample} \times 100 \quad (2)$$

Crude fat was determined using the Soxhlet method. Samples were weighed into a thimble and loose plug fat-free cotton wool fitted into the top of the thimble with its content inserted into the bottom extractor of the Soxhlet apparatus. A flat bottom flask (250 ml) of known weight containing 150 – 200 ml of 40 – 60ºC hexane was fitted to the extractor. The apparatus was heated and fat extracted for 8 h. The solvent recovered and the flask (containing oil and solvent mixture) was transferred into a hot air oven at 105ºC for 1 h to remove the residual moisture and to evaporate the solvent. It was then transferred into the desiccator to cool for 15 min before weighing. The percentage fat content was calculated as:

$$\%\,Fat = \frac{Weight\ of\ extracted\ fat}{Weight\ of\ sample} \times 100 \quad (3)$$

For fibre determination, 2 g of the sample were extracted using Diethyl ether. This was digested and filtered through the california Buchner system. The resulting residue was dried at 130±2ºC for 2 h, cooled in a dessicator and weighed. The residue was transferred into a muffle furnace and ignited at 550ºC for 30 min, it will be cooled and weighed. The percentage crude fibre content was calculated as:

$$\%\,Crude\ fibre = \frac{Final\ weight\ of\ crucible - Initial\ weight\ of\ crucible}{weight\ of\ sample} \times 100 \quad (4)$$

The Kjeldahl method was used to determine the percentage crude protein. Two (2) grams of sample was weighed into a Kjeldahl digestion flask using a digital weighing balance (3000 g x 0.01 g 6.6LB). A catalyst mixture weighing 0.88 g (96% anhydrous sodium sulphate, 3.5% copper sulphate and 0.5% selenium dioxide) was added. Concentrated sulphuric acid (7 ml) was also added and swirled to mix content. The Kjeldahl flask was heated gently in an inclined position in the fume chamber until no particles of the sample adhered to the side of flask. The solution was heated more strongly to make the liquid boil with intermittent shaking of the flask until clear solution was obtained. The solution was allowed to cool and diluted to 25 ml with distilled water in a volumetric flask. Ten (10) ml of diluted digest was transferred into a steam distillation apparatus. The digest was made alkaline with 8 ml of 40% NaOH. To the receiving flask, 5 ml of 2 % boric acid solution was added and 3 drops of mixed indicator dropped. The distillation apparatus was connected to the receiving flask with the delivery tube dipped into the 100 ml conical flask and titrated with 0.01 HCl. A blank titration was prepared. The percentage nitrogen was calculated using the formula:

$$\%\ \mathrm{Nitrogen} = \frac{(\mathrm{S-B}) \times 0.0014 \times 100 \times \mathrm{D}}{\mathrm{sampleweight}} \quad (5)$$

Where, S = Titre value of the digested sample. B = Titre value of the blank. S - B = Corrected titre, D = Diluted factor, % Crude Protein = % Nitrogen x 6.25 (correction factor).

Carbohydrate content was determined by difference as follows:

$$\%\ \mathrm{Carbohydrate} = 100 - (\%\mathrm{moisture} + \%\mathrm{Protein} + \%\mathrm{Fat} + \%\mathrm{Ash} + \%\mathrm{Fibre}) \quad (6)$$

2.2.2 Determination of mineral content of cookie samples

The mineral content of the formulated samples was evaluated using the method described by [9]. A gram of dried samples will be digested with 2.5 ml of 0.03N hydrochloric acid (HCl). The digest was boiled for 5 min, cooled at room temperature, and transferred to a 50 ml volumetric flask and made to the mark with diluted water. The resulting digest was filtered with ashless Whatman No. 1 filter paper. The filtration of each sample was then analyzed for mineral (calcium, phosphorus, magnesium, iron, sodium, potassium) contents using an atomic absorption spectrometer using standard wavelengths. The real values were extrapolated from the respective standard curves. The values obtained were adjusted for the HCl-extractability for the respective ions. All determinations were made in triplicate.

2.2.3 Determination of the vitamin content of cookie samples

The method of AOAC [8] using the colorimeter was adopted. Vitamins A, B1, B2, B3, B6 and B9 were determined.

2.2.4 Determination of the amino acid profile

Amino acids composition was quantified after hydrolysis using model 120A PTH amino acid analyzer (HPLC) in reversed-phase column, after a derivatization with 9-fluorentylmethyl chloroformate and a fluorescence detector [8]. The sample was dried at 70 °C to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator and loaded into the biosystem PTH Amino Acid Analyzer. The concentration of the individual amino acids was calculated in relation to the protein content.

2.2.5 Evaluation of sensory quality attributes of cookie samples

A panel of 30 habitual individuals was used for this study, where a 9-point hedonic scale was used; with 9 representing like extremely and 1 representing dislike extremely.

2.3 Statistical Analyses

Data were generated in triplicate and subjected to analysis of variance (ANOVA). Means were tested for significant differences using Duncan's multiple range test (DMRT). Significance was accepted at $p<0.05$.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Cookies from Insect Meal-supplemented Cookies

The result of the proximate composition of the cookies made from insect meals (wheat/cricket) meal and wheat/caterpillar meal blends is presented in Table 3.

The ash content of cookies from both cricket and caterpillar increased significantly across all samples. This result is an indication that both crickets and caterpillars contain a good amount of ash. Murugu et al. [3] and Bukkens [10] reported that the ash content of crickets and caterpillar is 2.36% and 4.00%, respectively, thus agreeing with the findings of this study that crickets and caterpillar contain a good amount of ash. Similar findings have been reported by [11] who mixed termite and wheat flours to produce cookies and found that the ash content of the cookies had increased across all formulations.

As observed, the moisture content of the cookies produced increased with the amount of cricket and caterpillar that was mixed into the formulation. Moisture content bears a relationship with the shelf stability of a food product in that the higher the moisture content, the lower the shelf stability and vice versa, aligning with the fundamental principles established by Igbabul et al. [12]. This implies that, while the addition of cricket and caterpillar meal to wheat improved the nutritional composition of cookies, it also makes them more prone to spoilage due to microbial activity as a result of increased moisture content. Cookies and other baked foods with more than 14% moisture are vulnerable to mold infestation and other forms of microbial attacks [13].

The addition of cricket and caterpillar meals to wheat increased the protein content of cookies across all formulations. Caterpillars and crickets, along with termites, have been reported by many researchers to be good sources of dietary protein. In separate reports [3], the reported protein content of cricket was 62.00% and the caterpillar was 76.04%. Womeni et al. [14] reported slightly higher protein values for crickets (64.89%) and caterpillars (77.16%).

The recommended dietary allowance (RDA) for protein is 15 mg/day and while the test samples both meet the RDA, cookies made from caterpillar fortified wheat flour provided higher protein values and would serve as a better source of animal protein for food fortification than crickets.

Cookies produced from wheat/caterpillar flour blends were also more fiber rich. Whereas the low fibre content of crickets was reported by [15], the caterpillar was reported to be high in fibre content by [16]. The amount of fiber contained by an insect has been attributed to the thickness of its chitin exoskeleton, which provides rigidity and support. The fiber contents recorded in this study also gives an insight into the understanding that composite flour cookies contain more digestible carbohydrates.

The test samples also demonstrated higher fat content with respect to the control sample (wheat flour). The higher fat content of insect meals may be pinpointed as the sole reason for the increase in the fat content of cookies when insect meals were added to wheat flour. The result also showed that the caterpillar contained a higher amount of fat than the crickets, which also received the backing from literature [14,17] that the caterpillar contains a higher amount of fat than the crickets.

The carbohydrate content of the cookies decreased as more cricket meal and caterpillar meal were added to the formulations. The result of this present study was in agreement with the findings of the Cheng et al. [18], who reported that in the combination of two or more raw materials to develop a new product, the carbohydrate content of the food will eventually increase as the protein content decreases due to the displacement of protein molecules by carbohydrate molecules. Cookies made from wheat flour/cricket meal blends were richer in carbohydrate than those from wheat flour/caterpillar meal blends.

3.2 Mineral Content of Cookies from Insect Meal-supplemented Cookies

The mineral content result of the mineral content of cookies prepared from wheat flour fortified with cricket and caterpillar meals is presented in Table 4.

The result showed that incorporation of both edible insects (cricket and caterpillar) significantly increased the mineral content of the cookies. An increase in the mineral content of cookies was expected with the addition of various edible insect meals, as several researchers reported that cricket and caterpillar are good sources of minerals (Nightingale et al., 2012); [19].

The addition of cricket meal and caterpillar meal to the flours significantly increased the calcium content of the cookies, which is an indication that edible insect meals are rich in calcium. Calcium is required in the body for the development and maintenance of healthy teeth and bones.

FAO, [20] reported that the calcium content of cricket was 132.14 mg/100g while [10] reported that the caterpillar contained 294.23 mg/100g of calcium, which in all cases was higher than the calcium content of 100% wheat flour (95.65 mg/100 g) reported in this study. The calcium RDA is 100 mg/day [21].

The magnesium content of the fortified cookies with edible insects meal was high and increased with increasing amount of edible insects meal into the formulations. This increase in magnesium content of the cookies indicates that the cricket and caterpillar meals are rich in magnesium. Magnesium is a vital mineral in the body as it helps to maintain normal nerve and muscle function [21]. Results in this study are in agreement with FAO [20] that reported that all mineral components in the caterpillar is higher than that in the cricket.

The result also shows that the amount of zinc in the flour increased as the formulations were varied to contain more edible insect's meal (cricket and caterpillar) meals. This trend is in line with reports by Naza [22]. Although the zinc values recorded in cookies prepared from both wheat flour / biscuit meal and wheat flour / carbohydrate meal were moderate, they were not high enough to account for the 8% daily zinc need by the human body [21].

The iron content of the edible insect meals (cricket and caterpillar) was observed to be higher than that of wheat flour, as the cookies showed a significant increase in the iron content as more edible insect meals were added to the formulations. Iron is required for human growth and synthesis of hemoglobin and myoglobin which are oxygen carriers in the blood and muscles, respectively [23]. The increase in iron content of the cookies was not as high as expected considering the fact that [24] had reported high values of 9.27 mg/100 g in cricket and 17.41mg/100 g in caterpillar, which is high enough to have caused more increase in cookie blends observed in this present study.

A high phosphorous content was recorded in all prepared cookie samples, and the amount of phosphorus contained in the samples increased as more edible insects' flour was added to the wheat flour. Phosphorus is an important component of teeth and bones. It is also available in DNA as phospholipids and the body needs 100 mg/day of phosphorous.

3.3 Vitamin Content of Insect Meal-supplemented Cookies

The vitamin content of the cookies produced are presented in Table 5. The composition of thiamin in the samples did not changed (p>0.05) as the formulations were varied to contain more edible insects (cricket and caterpillar) meal. Thiamin is required in the body to help body cells convert carbohydrate into energy, aid muscle contraction, and conduction of nerve signals [23]. FAO [20] reported 0.71 mg/100 g and 0.75 mg/100 g of vitamin B_1 in cricket and caterpillar meals, respectively.

The addition of more edible insect meal to the formulation caused a slight increase in the riboflavin content of the cookies. However, this increase was insignificant. Vitamin B_2 is essential for human health. It is water-soluble and crucial for breaking down food components, absorbing other nutrients, and maintaining tissues [25].

Increase substitution with the insect meals had no significant (p>0.05) increase in the vitamin B6 content. Vitamin B_6 (pyridoxine) is involved in the metabolism of protein and glucose and the manufacture of hemoglobin. It also helps boost brain performance. The low amount of vitamin B_6 recorded in this study agrees with the report that edible insects are low in vitamins, especially water-soluble vitamins [10].

The formulated cookies contained appreciable amounts of vitamin A that decreased significantly (p<0.05) with increasing amount of cricket and caterpillar meals that were added to the formulations. Vitamin A is needed for protection and maintenance of sight [23]. This result showed that the wheat flour used in this study was richer in vitamin A than the insect meals [21]. Higher vitamin A values were recorded in cookies prepared from wheat flour/cricket meal blends than in cookies made with wheat flour/caterpillar meal blended cookies. This result indicates that crickets are richer in vitamin A than caterpillar. The result published by [10] showed that crickets had 10.21 mg/g of vitamin A, while caterpillars contained 8.69 mg/g of the same vitamin.

3.4 Essential Amino Acid Content of Insect Meal-supplemented Cookies

The essential amino acids of the wheat-insect meal cookies are are presented in Table 6. The results indicate that increasing the ratio of insect meal to wheat in the cookie samples significantly enhanced the amino acid content across all measured amino acids: lysine, methionine, threonine, isoleucine, leucine, phenylalanine, valine, tryptophan, and histidine [26]. For instance, lysine content increased from 3.21 in the 100:0 wheat sample to 4.85 in the 80:20 wheat:CP sample. Similar trends were observed for methionine, which increased from 0.76 to 1.85, and threonine, which rose from 1.56 to 2.88, as the proportion of CP increased [23]. This pattern was consistent across all other amino acids, with notable increments as the proportion of cricket powder increased, highlighting the superior amino acid profile of cricket and caterpillar meals compared to wheat.

3.5 Non-essential Amino Acid Content of Insect Meal-supplemented Cookies

The essential amino acids of the wheat-insect meal cookies are presented in Table 7. The results show that increasing the proportion of insect meal in wheat samples significantly enhanced the content of several amino acids: serine, cysteine, tyrosine, alanine, aspartic acid, glutamic acid, glycine, proline, and arginine. For instance, serine content increased from 2.45 in the 100:0 wheat sample to 4.92 in the 80:20 wheat:insect meal sample. Cysteine content rose from 1.99 to 2.80, and tyrosine content increased from 4.82 to 6.14. Alanine content showed a notable increase from 0.75 to 2.42 [27]. Aspartic acid and glutamic acid also saw significant increases, with aspartic acid rising from 4.35 to 7.94 and glutamic acid from 8.12 to 13.60. Additionally, glycine increased from 2.06 to 3.94, proline from 1.29 to 5.85, and arginine from 1.26 to 4.63 [28]. The Least Significant Difference (LSD) values confirm that these increases are statistically significant, indicating that the integration of insect meal into wheat-based formulations significantly boosts their amino acid profiles, thus enhancing their nutritional value.

3.6 Sensory Attributes of the Insect Meal-supplemented Cookies

As observed in Table 8, cookies made from wheat flour/cricket meal were more acceptable than those made from wheat flour/caterpillar meal due to the darker and coarser nature of caterpillar meals. Cookies for samples 85:15 (8.30) for wheat/cricket cookies and 85:15 (8.11) for wheat/caterpillar cookies had the highest mean score in overall acceptability.

Table 3. Proximate composition (%) of cookies from insect meal-supplemented cookies

Wheat: IM	Ash		Moisture		Fat		Protein		Fibre		Carbohydrate	
	CK	CP	CK	CP	CK	CP	CK	CP	CK	CP	CK	CP
100:0	0.91[a]		3.50[a]		0.21[a]		10.44[a]		0.08[a]		84.86[e]	
95:5	1.75[b]	4.90[b]	3.54[a]	9.56[b]	2.63[b]	3.17[b]	16.62[b]	19.37[b]	0.68[b]	1.05[b]	74.78[d]	61.95[d]
90:10	2.18[c]	5.82[c]	3.73[a]	10.21[c]	2.80[c]	3.63[c]	19.00[c]	22.19[c]	1.16[c]	1.99[c]	70.33[c]	57.16[c]
85:15	2.82[d]	6.17[d]	4.51[b]	10.80[d]	3.12[d]	4.44[d]	20.85[d]	27.12[d]	1.29[c]	2.41[d]	67.41[b]	51.06[b]
80:20	3.64[e]	6.62[e]	6.50[c]	11.04[e]	3.84[e]	4.86[e]	21.88[e]	30.84[e]	1.51[d]	3.00[e]	62.63[a]	46.04[a]
LSD	0.50	0.44	0.32	0.50	0.15	0.15	1.02	2.41	0.26	0.11	1.73	2.17

IM: Insect Meal; CK: Cricket; CP: Caterpillar

Table 4. Mineral content of cookies from insect meal-supplemented cookies (mg/100 g)

Wheat: IM	Calcium		Zinc		Potassium		Magnesium		Iron		Sodium		Phosphorous	
	CK	CP	CK	CP	CK	CP	CK	CP	CK	CP	CK	CP	CK	CP
100:0	95.65[a]		2.15[a]		485.27[a]		35.63[a]		3.13[a]		45.27[a]		84.14[a]	
95:5	124.16[b]	133.63[b]	2.47[b]	2.51[b]	522.08[b]	531.06[b]	41.16[b]	44.55[b]	4.12[b]	5.12[b]	48.77[b]	51.64[b]	91.63[b]	96.36[b]
90:10	152.43[c]	168.87[c]	3.15[c]	3.33[c]	541.14[c]	544.65[c]	51.35[c]	52.47[c]	5.15[c]	5.78[c]	52.55[c]	55.86[c]	105.13[c]	114.63[c]
85:15	163.52[d]	183.75[d]	3.86[d]	4.16[d]	611.03[d]	620.06[d]	60.29[d]	63.47[d]	5.42[c]	5.95[d]	61.74[d]	68.86[d]	111.03[d]	125.15[d]
80:20	174.28[e]	192.65[e]	3.95[e]	4.37[d]	784.17[e]	791.28[e]	65.97[e]	67.13[e]	6.12[d]	6.53[e]	70.54[e]	77.62[e]	122.77[e]	130.86[e]
LSD	1.05	1.05	0.11	0.30	2.53	1.50	0.50	1.05	0.50	0.10	0.44	1.05	1.02	1.05

Values are means ± standard deviation of 3 replicate determinations
Means within a row with the same superscript were not significantly different (p>0.05)

Table 5. Vitamin content of insect meal-supplemented cookies (mg/100 g)

Wheat: IM	B_1		B_2		B_6		B_9		A	
	CK	CP	CK	CP	CK	CP	CK	CP	CK	CP
100:0	0.66^{a}		1.13^{a}		0.17^{a}		0.34^{a}		17.92^{a}	
95:5	0.68^{a}	0.73^{a}	1.34^{a}	1.35^{a}	0.19^{a}	0.22^{a}	0.42^{a}	0.43^{a}	16.24^{b}	15.84^{b}
90:10	1.03^{b}	1.25^{b}	1.52^{a}	1.61^{b}	0.33^{a}	0.35^{a}	0.46^{a}	0.65^{b}	14.25^{c}	12.83^{c}
85:15	1.34^{b}	1.45^{c}	1.64^{a}	1.67^{b}	0.44^{a}	0.42^{a}	1.03^{b}	1.05^{c}	12.15^{d}	9.75^{d}
80:20	1.62^{c}	1.65^{d}	1.71^{a}	1.75^{b}	0.45^{a}	0.47^{a}	1.34^{b}	1.35^{d}	9.95^{e}	6.50^{e}
LSD	0.37	0.17	0.60	0.25	0.10	0.09	0.35	0.22	0.50	1.00

Values are means ± standard deviation of 3 replicate determinations.
Means within a row with the same superscript were not significantly different (p>0.05).
KEY: B_1 = Thiamin (Thiamine); B_2 = Riboflavin; B_6 = pyridoxine; B_9 = folate; A = retinol

Table 6. Essential amino acid profile of insect meal-supplemented cookies (g/100 g)

Samples	Wheat: IM									LSD	
	100:0	95:5		90:10		85:15		80:20			
		CK	CP	CK	CP	CK	CP	CK	CP	CK	CP
Lysine	3.21^{a}	3.61^{b}	3.77^{b}	4.16^{c}	4.05^{c}	4.93^{d}	4.23^{d}	5.00^{e}	4.85^{e}	0.22	0.15
Methionine	0.76^{a}	1.14^{b}	1.24^{b}	1.32^{c}	1.42^{c}	1.53^{d}	1.63^{d}	1.75^{e}	1.85^{e}	0.15	0.10
Threonine	1.56^{a}	2.25^{b}	2.40^{b}	2.65^{c}	2.68^{c}	2.76^{c}	2.80^{d}	3.15^{d}	2.88^{d}	0.15	0.10
Isoleusine	1.04^{a}	2.85^{b}	2.98^{b}	3.04^{c}	3.08^{c}	3.66^{d}	3.67^{d}	3.97^{e}	4.02^{d}	0.10	0.50
Leusine	3.93^{a}	5.34^{b}	7.27^{b}	7.23^{c}	8.02^{c}	8.89^{d}	8.20^{c}	9.13^{d}	8.79^{d}	1.00	0.61
Phenylalanine	3.85^{a}	3.88^{a}	4.35^{b}	4.87^{b}	4.99^{c}	5.03^{c}	5.22^{c}	5.55^{d}	5.88^{d}	0.10	0.50
Valine	2.25^{a}	3.02^{b}	4.18^{b}	4.27^{c}	4.73^{c}	4.82^{d}	5.01^{d}	5.61^{e}	5.64^{e}	0.10	0.11
Tryptophan	3.26^{a}	3.79^{b}	4.12^{b}	4.21^{c}	4.31	4.66^{d}	4.75^{d}	4.79^{e}	4.82^{e}	0.15	0.15
Histidine	2.85^{a}	3.86^{b}	3.92^{b}	3.95^{c}	3.83^{c}	4.40^{c}	3.99^{d}	4.67^{d}	4.20^{e}	0.50	0.10

Values are means ± standard deviation of 3 replicate determinations
Means within a row with the same superscript were not significantly different (p>0.05)

Table 7. Nonessential amino acid profile of insect meal-supplemented cookies (g / 100 g)

Samples	Wheat: Insect Meal										
	100:0	**95:5**		**90:10**		**85:15**		**80:20**		**LSD**	
		CK	**CP**	**CK**	**CP**	**CK**	**CP**	**CK**	**CP**	**CK**	**CP**
Serine	2.45[a]	3.12[b]	3.79[b]	3.33[c]	4.17[c]	3.45[d]	4.55[d]	3.78[e]	4.92[e]	0.10	0.31
Cysteine	1.99[a]	2.00[b]	2.15[b]	2.16[c]	2.44[c]	2.32[d]	2.65[d]	2.58[e]	2.80[d]	0.15	0.15
Tyrosine	4.82[a]	5.63[b]	5.65[b]	5.82[c]	5.77[c]	5.94[c]	5.92[d]	6.14[d]	6.14[e]	0.15	0.10
Alanine	0.75[a]	1.72[b]	1.72[b]	2.15[c]	1.93[c]	2.27[c]	2.06[c]	2.54[d]	2.42[d]	0.21	0.15
Aspartic acid	4.35[a]	5.52[b]	7.15[b]	7.35[c]	7.29[b]	7.98[d]	7.86[c]	8.12[c]	7.94[c]	0.50	0.20
Glutamic acid	8.12[a]	9.14[b]	11.46[b]	11.12[c]	12.14[c]	13.23[d]	12.88[d]	15.55[e]	13.60[e]	0.84	0.15
Glycine	2.06[a]	3.42[b]	3.42[b]	3.66[c]	3.53[c]	3.99[d]	3.77[d]	4.26[e]	3.94[e]	0.10	0.10
Proline	1.29[a]	1.84[b]	2.28[b]	2.27[c]	3.06[c]	2.95[d]	4.05[d]	3.32[e]	5.85[e]	0.10	0.10
Arginine	1.26[a]	2.24[b]	2.27[b]	2.33[c]	2.88[c]	3.05[d]	3.12[d]	3.24[d]	4.63[e]	0.17	0.10

Values are means ± standard deviation of 3 replicate determinations
Means within a row with the same superscript were not significantly different (p>0.05)

Table 8. Sensory evaluation of insect meal-supplemented cookies

Wheat: IM	**Appearance**		**Aroma**		**Texture**		**General acceptability**	
	CK	**CP**	**CK**	**CP**	**CK**	**CP**	**CK**	**CP**
100:0	8.06[a]		7.10[b]		7.56[a]		7.57[b]	
95:5	8.00[a]	7.80[d]	7.51[b]	7.65[c]	8.04[c]	7.68[b]	7.74[d]	7.71[c]
90:10	7.94[a]	7.66[c]	7.72[c]	7.79[b]	8.42[d]	7.72[b]	7.80	7.79[c]
85:15	7.60[b]	7.36[b]	8.47[b]	8.11[a]	8.50[d]	8.33[a]	8.30[c]	8.11[b]
80:20	6.36[c]	6.26[a]	6.07[a]	6.08[a]	7.78[b]	6.68[a]	6.73[a]	6.34[a]
LSD	0.10	0.12	0.42	0.10	0.15	0.22	0.10	0.20

Values are means ± standard deviation of 3 replicate determinations
Means within a column with the same superscript were not significantly different (p>0.05)

This was expected as they were the most preferred cookies in aroma and texture. Cookies 80:20 were the least preferred products in overall acceptability (6.73) for wheat/cricket cookies and (6.34) for wheat and caterpillar cookies. This was also not strange, as it was the least preferred in all the sensory parameters that were evaluated. Both Cookies for samples 85:15 can be produced on a commercial scale with an assured confidence in consumers' acceptance and high marketability, because they had the highest mean score in overall acceptability.

4. CONCLUSION

The addition of cricket and caterpillar meals to wheat flour produced cookies with rich nutritional profile. The protein and mineral content of the cookies were increased to levels that were high enough to provide consumers of the cookies with the recommended dietary allowance (RDA) of the respective nutrients. Although cricket meal fortified cookies were rich in nutrients, caterpillar meal fortified cookies were comparatively richer. All the edible insects-fortified cookies contained high protein, mineral and amino acid contents but samples 85:15 (85% wheat flour + 15% cricket meal) and 85:15 (85% wheat flour + 15% caterpillar meal) which were also high in nutrients recorded better sensory attributes and were therefore, selected as the best wheat flour + cricket meal and wheat flour + caterpillar meal blends for cookies production. The high nutritional quality of cookies produced in this study can be utilized as an alternative protein source to arrest the protein intake deficiency prevalent among Nigerians.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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